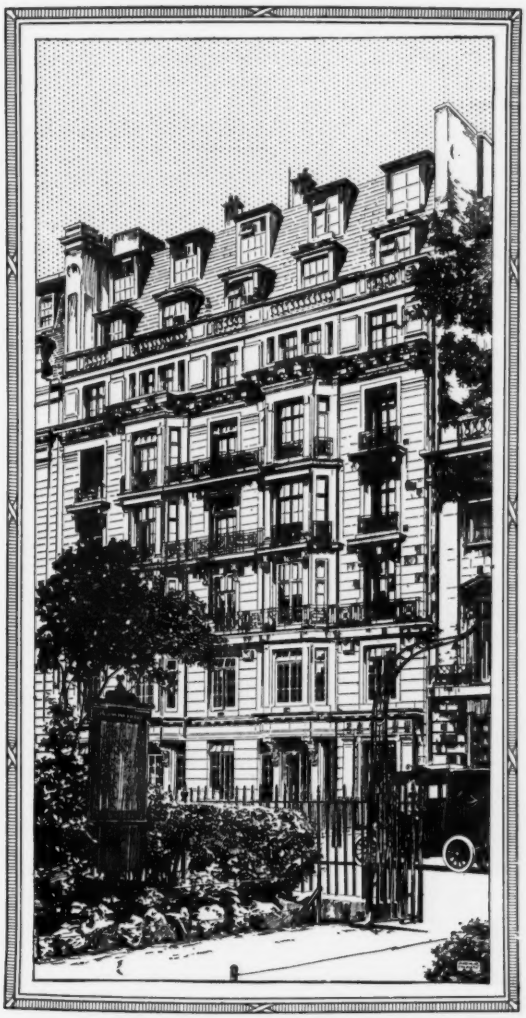
The ENGLISH ELECTRIC JOURNAL



Queen's House from Lincoln's Inn Fields

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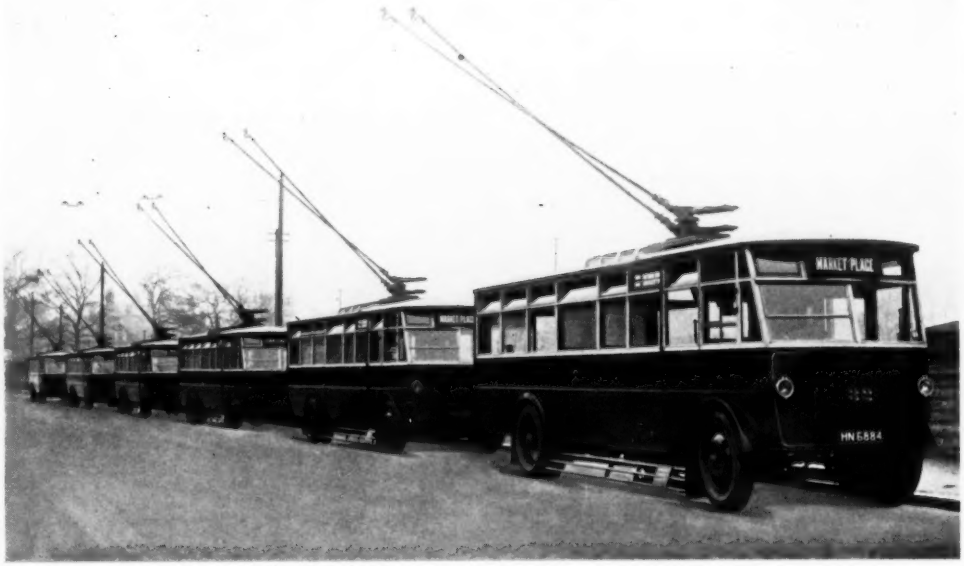
New Fleets of the Newest Passenger Vehicle



A Note in this issue draws attention to the rapidity with which Trolley Buses are being adopted for Urban Transport Services. The two views reproduced above were taken in the vicinity of Darlington and of Maidstone, and show fleets of English Electric buses recently put into service in those towns.

The English Electric Journal

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All Communications respecting Editorial Contents should be addressed to THE EDITOR, THE ENGLISH ELECTRIC JOURNAL, QUEEN'S HOUSE, KINGSWAY, LONDON, W.C.2.

EDITORIAL.

In this issue we give prominence to some recently completed contracts for trolley buses because of the world-wide interest now being shown in this vehicle as an auxiliary to tramcars or a substitute for them. It has proved that it can give the public unrivalled service, in many cases at a lower running cost than any other form of urban transport. This Company has taken every measure to ensure the production of an efficient, comfortable and durable vehicle and has secured the bulk of orders placed in recent times.

The magnitude of the power plant required in a broadcasting station will be a revelation to many of our readers, and the problems involved will be appreciated when it is realised that a direct-current supply has to be given at a pressure of 12,000-volts. Some of us who are not so young as we were, will remember the qualms experienced when A.C. transmission — not to mention

generation—at 10,000 volts was first undertaken. Insulation was a tremendous problem, and the idea of dealing with a still higher voltage on commutators of orthodox design would have been scouted as ridiculous. And now at Brookman's Park and elsewhere such commutator machines are in almost continuous service and are proving themselves to be as robust and reliable as any standard direct-current plant.

The most interesting feature in the design of the machines is the arrangement whereby the electric stress on the insulation is transferred in large part from the armature windings and commutators to a secondary layer of insulation built into the armature hub, where a thoroughly sound mechanical construction can be used and temperature variations are a minimum. The bedplates, shafts, frames and bearings are all at earth potential and no insulated couplings are required. The arrangement is an invention of J. E. Calverley and W. E. Highfield, and the patent rights are held by this Company.

Readers who desire further particulars of the Brookman's Park station will find them in a paper read recently before the Institution of Electrical Engineers by Captain P. P. Eckersley and N. Ashbridge.

The Company's Dick Kerr Works at Preston have for long specialised in high-voltage direct-current plant and machines for the Thury system supplied many years ago are still in active service.

This number of the Journal also contains descriptions of recent automatic substation equipments, of a large steam turbine set, and of the electrification of brick-making plants, which show the latest developments in these lines.

The Rapid Progress of the Trolley Bus.

The New "A.E.C.—English Electric" Series.

During the last few years the Electric Trolley Bus has emerged from the stage in which it was on trial technically and economically, and it is now widely recognised to be the vehicle that is best suited to certain conditions of urban passenger transport. Where it has already been introduced the fleets are being continually increased, and almost every week marks the addition of another transport undertaking in some part of the world to the ranks of those who have adopted the new vehicle. The Electric Trolley Bus has been described as the Rolls-Royce of the public, and rightly so if this conveys the idea of comfortable riding, easy and powerful acceleration, and the entire absence of noise. Since they draw their power from established central stations and sub-stations in most of which special plant has been installed for a tramway system, they have the additional merit of utilising existing power facilities and of contributing to the support of that important national industry—coal production.

Readers of this Journal will be aware of the pioneer work of this Company in the field of trolley bus development and of the foremost position it has attained as suppliers of these vehicles, following a similar record in the field of tramway and tramcar construction. As builders of electrical equipment, bodywork and complete vehicles for over thirty years, the Company is able to apply a wide and varied experience which ensures that its products are fully adequate for the most exacting service conditions. Readers may also have seen the announcement made recently of the conclusion of an arrangement between the Associated Equipment Company—the "Builders of London's Buses,"—and The English Electric Company, for the marketing of

One of Nottingham's new Fleet.

a series of trolley buses of distinctive design. This announcement ran as follows :—

"As the premier manufacturers of Petrol Buses and Electric Trolley Buses respectively, the Associated Equipment Company, Ltd., and The English Electric Company, Ltd., have arranged to collaborate in putting on the market a line of single-motor low-loading trolley omnibuses. These vehicles, which will shortly be put on test, will have as their basis the A.E.C. 'Regal,' 'Regent' (4-wheel), and 'Renown' (6-wheel) chassis. The lines of vehicles will include single and double-deck types with the following wheelbases and seating capacities :—

Model.	Seats.	Decks.	Wheels.	Wheelbase.
661T	50/52	double	4	15′ 6½″
662T	30/34	single	4	17′ 0″
663T	60	double	6	16′ 6″

The last-mentioned can be supplied with a wheelbase of 18′ 7″.

"In these new vehicles the A.E.C. will manufacture the chassis and components. The electrical equipment and the bus bodies will be manufactured by The English Electric Company."

The vehicles of this series, in which a single motor is mounted forward in a similar position to that of a petrol engine, will be distinguished by their relatively light weight and low loading height. For those cases where a motor mounted in a forward position is not favoured, the complete

Bradford has a large fleet of "English Electric" Trolley Buses. Buses turning at a City terminus.

"English Electric" vehicle, in which the motor of either single or twin type is mounted in the middle of the chassis frame, can still be supplied. With the twin type of motor, series-parallel control is obtainable, when desired. The relative merits of the different types depend largely upon local considerations.

The opportunity has been taken to include in this note and in the frontispiece a number of illustrations of vehicles recently put into service throughout the country. These buses embody the best practice in this form of transport, and all parts are specially designed, not merely adapted, for the peculiar needs of railless traction. The illustrations show trolley buses supplied in completion of the following contracts :—

Bradford	...	12 six-wheel, double-deck.
		11 four-wheel, single-deck
Darlington	...	6 ,, ,,
Maidstone	...	7 six-wheel, double-deck
Nottingham	...	6 ,, ,,

Similar equipments are in hand for Pontypridd, Southend and Christchurch, N.Z.

High-Tension D.C. Generators for Radio Transmitting Stations;

with a Description of the Plant in Operation at the London Regional Station of the British Broadcasting Corporation.

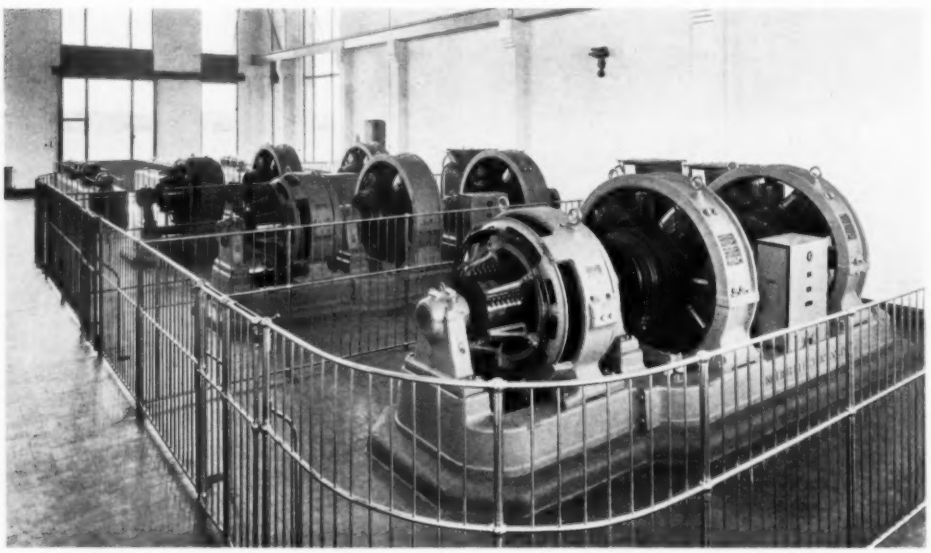


Fig. 1. Three 12,000-volt Generators at the London Regional Station, Brookman's Park.

The English Electric Company has been actively engaged in the design and manufacture of high-tension D.C. generators for upwards of 25 years, and during this period has constructed a large number of machines for operating in circuits of 5,000 to 20,000 volts, and with outputs up to 500 kilowatts per commutator, together with D.C. machines of other types for voltages up to 120,000.

Practically all high-power wireless stations throughout the world which operate on high-tension direct-current supplied from commutating machines are equipped with generators built at the Preston Works of the Company. Many of these machines delivering their output at voltages of 5,000 to 10,000 have been in regular service since the very earliest days of radio communica-

tion. The Company's unique experience in this field enables it to put forward machines of high voltage with complete confidence in their ability to give continuous service over a large number of years.

One great advantage of this type of machine is its high efficiency compared to that of the thermionic rectifier; now that power units of quite large outputs are being installed for radio transmission purposes the question of efficiency is becoming more important. It has been stated* that the use of generators with an efficiency of, say, 83 per cent. as against rectifiers with an efficiency of 60 per cent. may lead to an annual saving of £1,000, or more, in a single modern broadcasting station. Further advantages of these machines are their flexibility as regards easy adjustment of the voltage and their immunity from the periodical interruptions of service which are occasioned by the burning out of valves.

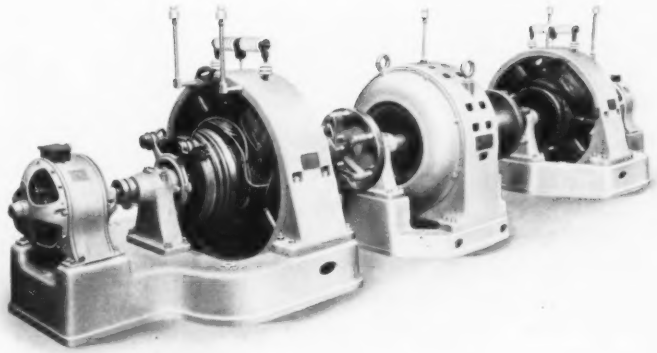


Fig. 2. An Early "English Electric" 10,000-volt Set.

Fig. 2 shows one of a number of motor generator sets built 20 years ago, some of which are still in regular operation. The set consists of two generators coupled to an A.C. motor, each generator delivering 50 kilowatts at 5,000 volts D.C. when running at 720 r.p.m. The two machines connected in series give an output of 100 kilowatts at 10,000 volts. The generators are mounted on separate insulated foundations, the drive being transmitted from the motor through insulated flexible couplings. Each generator is provided with a potential equaliser mounted on top of the magnet frame, which maintains the frame at a potential midway between that of the brushes and limits the dielectric stress on the slot insulation to 2,500 volts, the insulated foundations providing the necessary insulation to ground.

A similar set of larger capacity and of later date is illustrated in Fig. 3. This is for 300 kilowatts output at 10,000 volts. The arrangement is similar to that of the set previously described, but the two generators are solidly coupled and mounted on one insulated foundation. One potential equaliser is provided for the set, but the slot insulation is reinforced by insulation of the armature hub, the potential from the windings to the frame being maintained at a maximum of 5,000 volts.

The durability of D.C. machines working at

* Journal of the Institution of Electrical Engineers, Vol. 66, p. 519.

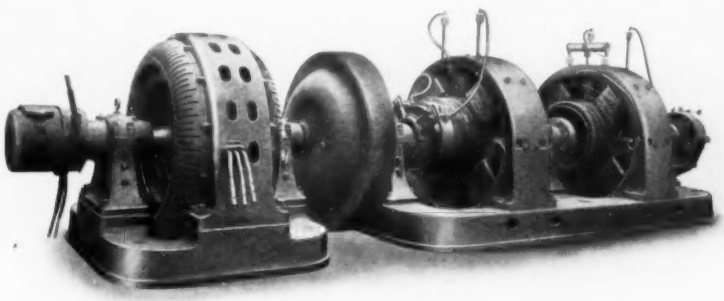


Fig. 3. A 10,000-volt set for an output of 300 kW.

high voltages depends almost entirely on the kind of insulation used in the slots of the armatures, and the dielectric stress to which it is subjected. To commutate well, a D.C. machine must have slots of comparatively small pitch compared with alternating current machines of similar voltage, and there is not the same amount of space available for insulation. With the full generated potential to ground the slot insulation will, therefore, be heavily stressed, and may deteriorate rapidly. 0.15 of an inch is probably the maximum space available for insulation to ground in the slot of a D.C. machine, and if the machine delivers, say, 15,000 volts, the average potential gradient will be 100,000 volts per inch. Under this stress any small air film in the insulation or between the coil and the slot will be heavily ionised, and the insulation will perish after a comparatively short life. Hence it is essential that the slot insulation for these machines should be of very high quality, and free from air pockets, and that the dielectric stress on the insulation should be limited to a value that it can withstand indefinitely.

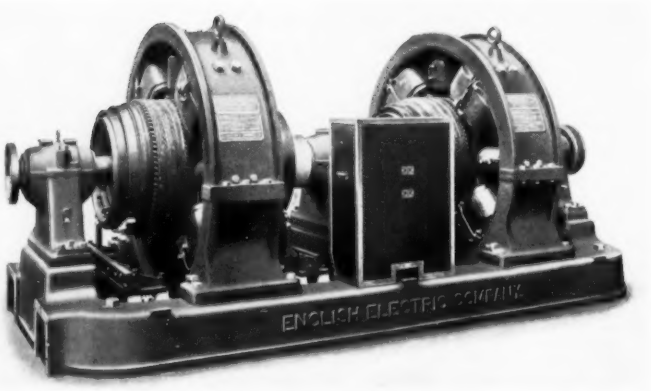


Fig. 4. A 12,000-volt Set for Broadcasting Service.

To avoid over-stressing the insulation, insulated foundations were used in the past, together with potential equalisers arranged to distribute the potential in the required manner. Insulated foundations, however, are cumbersome and expensive, while insulated couplings are undesirable and may be costly to manufacture and maintain.

The potential equalisers on the machines described are in effect high-resistance shunts across the machine, and carry a small current continuously. Thus, there is a small continuous waste of energy accompanied by gradual deterioration of the resistance material. Though these resistances were simple and easily renewable, it is obvious that a more satisfactory device would be one which would act as a potential circuit alone, and become a conducting circuit only in the event of a fault developing.

These features have been kept in mind

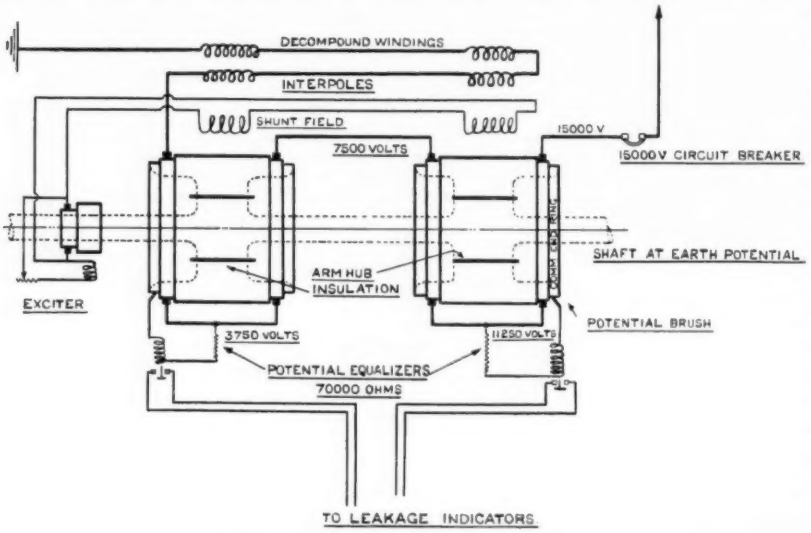


Fig. 5. Connections of a 15,000-volt Set.

when designing the " English Electric " graded-potential machines, which have been developed to meet the very exacting conditions of modern broadcasting, where a shut-down during service must be avoided at all costs.

The slot insulation is of the highest quality pressed mica, and under normal conditions it can endure indefinitely the stress to which it is subjected. The major insulation to ground is incorporated in the armature hub where it can be made of liberal thickness and be built in solidly, in a position which is both remote from any appreciable temperature variations and also free from the limitations imposed on slot insulation by the number and shape of the armature conductors, and the allowable sizes of armature slots. The armature hub insulation takes the form of a layer of pressed mica with liberal creeping distances at the ends where the insulation emerges from the solid material forming the hub. This insulation is capable of withstanding 20,000 volts for a long period, and is tested with a 50-cycle alternating pressure of this value for one minute. The armature windings and commutators are tested at 11,000 volts A.C. to the armature core, making a total test pressure of 31,000 volts A.C. to ground, though the breakdown value of 15,000 volts D.C. is equivalent to no more than 10,500 volts A.C.

The number of commutators in series is decided by considerations of good potential grading on the insulation, the maximum voltage between bars and the dielectric stress on the slot insulation; an even number is the more favourable for a suitable potential grading. It is quite possible to commutate 10,000 volts or more on a single commutator, especially for small outputs, though with the steep potential gradients which are then present, the machine will become very sensitive and liable to flash over, even on a perfectly steady load, if the commutator becomes at all dirty or there is a small irregularity on its surface. For absolute security and continuous service without an undue amount of attention, the voltage per commutator should be kept to a value which takes these facts into account, and the permissible voltage will vary with the kilowatt rating of the machine.

Fig. 4 shows one of the 160 kW. 12,000 volt motor generator sets which were put into operation last year at the London Regional Station, and Fig. 1 is a view of these sets in operation.

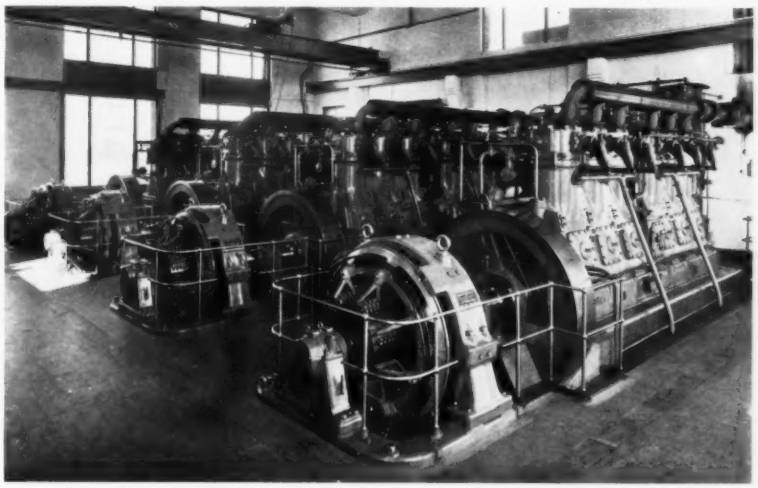


Fig. 6. Four 200 kW. Generators at Brookman's Park.

Each of these sets consists of a D.C. motor driving two generators, each having one armature and two commutators, and the four commutators are connected electrically in series. Each generator is of four-pole construction in accordance with the Company's usual practice for high-voltage machines. They have found by experience that for any but the smallest sizes the abnormally long end windings on the armatures of two-pole machines are difficult to insulate, and moreover, are mechanically weak when wound with copper of the very small section required for machines of this output and voltage.

The interpoles and series windings are connected on the negative side of the armature, as shown on the diagram of connections, Fig. 5 of this particular set.

The voltage per commutator is 3,000, and this is the total dielectric stress on the slot insulation. A potential equaliser and trip gear is provided for each generator to maintain the potential of each armature core at its correct value midway between the extreme potentials of the two commutators, and to distribute the dielectric stress between the slot insulation and that contained in the armature hub.

The limiting resistance in the potential equaliser circuit has a value of 70,000 ohms and during normal running does not carry any current. It makes connection with the rotating masses by means of a light brush running on an extension to one of the commutator end rings. In the event of current existing in this resistance due to leakage or insulation breakdown, a relay will close two contacts on a low potential circuit which can be arranged to operate a leakage indicator gear and give either visual or aural warning of the fault. One insulation fault in either the slot insulation or the hub insulation will not inevitably result in an immediate shutdown, as all insulations are capable of withstanding any additional potentials which can be applied to them under fault conditions, and thus allow time for another set to be brought into service. Hence, this insulation scheme provides double security and gives ample warning of any insulation defect.

The potential equaliser and leakage trip gear consume no energy and require no attention, but can be relied on to operate if called on to do so, even after many years of inactivity. As provision is made for tripping and resetting the gear at any time even when the machine is in service, its proper working can be periodically confirmed.

All highly inductive windings on the machines which are connected in the high-tension circuit consist of coils having special formation to safeguard them against insulation breakdown between turns, due to surges or impulses which may possibly get through to them from the load or smoothing system. If necessary these particular windings may be provided with high-resistance non-inductive shunting circuits.

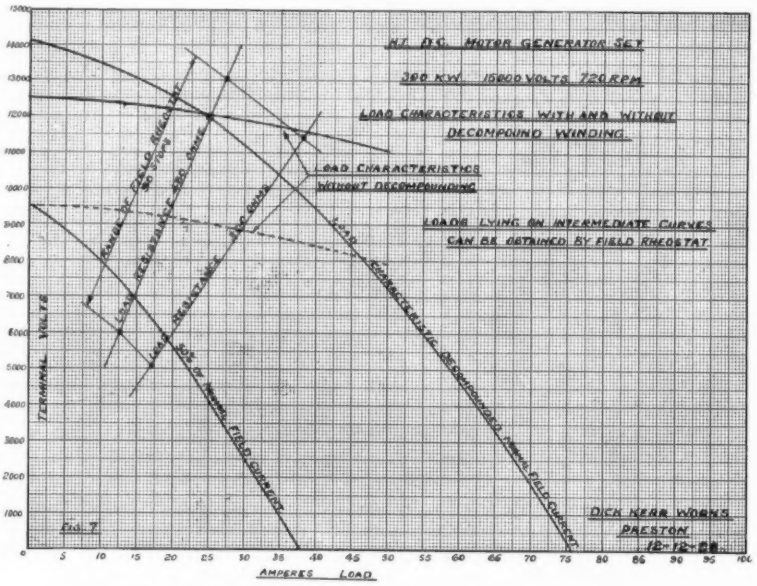

M.V. D.C. MOTOR GENERATOR SET
300 KW 15000 VOLTS 720 RPM
LOAD CHARACTERISTICS WITH AND WITHOUT DECOMPOUND WINDING.
LOAD CHARACTERISTICS WITHOUT DECOMPOUNDING
LOADS LYING ON INTERMEDIATE CURVES CAN BE OBTAINED BY FIELD RHEOSTAT
TERMINAL VOLTS
AMPERES LOAD
DICK KERR WORKS PRESTON

Fig. 7. Characteristic Curves for 15,000-volt, 20 ampere Set.

Interpole coils and series coils, when used, are connected on the earth side of the armature, and if necessary can be insulated for the full potential, though it is preferable to keep all windings on the frame structure to a potential not far removed from that of earth.

The high-tension machines at Brookman's Park are completely enclosed by an earthed steel railing, the entrance gates in which are interlocked with the main switchgear to ensure that they are

closed and locked before the plant can be started up.

Machines of similar output which have been supplied recently for radio communication purposes were designed so that the total output was furnished by one armature having two commutators each for 6,000 volts. In this case the motor and generator are self-contained machines, each with two roller bearings, and are connected by a flexible coupling. Another variation from the Brookman's Park machines consists in the provision of enclosing covers with interlocked doors over each H.T. commutator, thus dispensing with the necessity of placing the whole of the machine in an earthed enclosure; the bearings, driving motor, and other parts can be inspected while the set is in operation.

Special attention has been paid to the elimination of ripples in the D.C. wave form, and any ripples that may exist will be of extremely small amplitude.

The machines are usually separately excited from an exciter or some external circuit, but can be provided with assisting or opposing compound windings as required. In some cases the machines are heavily decompounded by their output current so that the generated voltage decreases rapidly with increasing load, and becomes practically zero when the output current reaches about three times normal.

Fig. 8. Switchboard in Transmitting Hall, Brookman's Park.

The current limiting effect of a machine of this type is then superior to that of the thermionic rectifier. A typical characteristic curve is given in Fig. 7 for a 15,000-volt, 20-ampere machine, and a curve is also shown giving the load characteristic of the same machine with the decompound winding disconnected.

The decompounded machine can be efficiently protected by means of a choke coil in series, so arranged that the rate of increase of current on short circuit does not exceed a value which can be checked by the decompound winding. In other cases where a choke of this nature is not

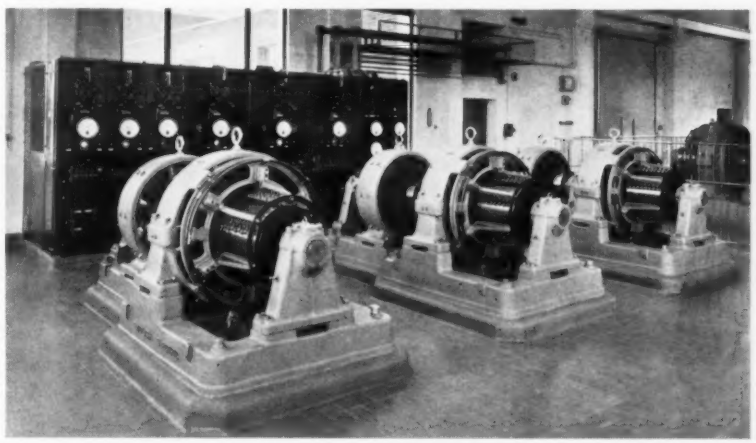


Fig. 9. Filament-current Motor-generators and Control Board at Brookman's Park.

allowable, and very good voltage regulation is necessary, an efficient circuit-breaker can be provided which will open the circuit in a very short interval of time and protect the machine and load from damage due to excessive current.

The frame of the machine operates at earth potential, but the insulating scheme provides for the negative terminal and all windings on the negative side to withstand a pressure test of 5,000 volts. Therefore, the actual earth connection can be made at a point remote from the machine.

A self-contained exciter is provided when necessary, the armature of which is overhung on an extension to the generator shaft, thus obviating the use of an extra bearing. The exciter field system is rigidly supported on an extension to the bedplate.

The machine will be perfectly stable over the wide range of voltage variation provided by the field rheostat. Fig. 7 shows the range of adjustment obtained by the field rheostat for two different external loads, one of these being 480 ohms to consume 25 amperes at 12,000 volts, and the other being assumed at 300 ohms. The rheostat will regulate the voltage and current along the line representing the load resistance. Below this range the voltage can be reduced to practically zero value by several steps.

The excitation system operates at earth potential, and is electrically remote from the high-tension side, so that no special insulation is necessary in the excitation circuit or control gear.

A complete motor-generator set with exciter has an efficiency of about 85 to 88 per cent. when delivering its normal output, the exact figure varying slightly with the size and type of motor. A suitable driving motor for either D.C. or A.C. supply can be provided and mounted on the same bedplate, the running speed of the generators in all cases being selected to suit either type of power system.

To complete the reference made to the plant at the London Regional Station it may be said that in addition to the high-tension D.C. generators already described, the majority of the power plant and control gear was manufactured by this Company. In the main Power Station are installed four 200-kW. shunt-wound generators, driven at 300 r.p.m. by oil engines and capable of giving their output at any pressure from 200 to 260 volts. For supplying the filament current there are three motor-generator sets, each having an output of 1,300 amperes at any pressure between 15 and 30 volts, while for battery-charging purposes two reversible motor-booster sets are provided which can give a continuous output of 400 amperes at 70 volts or 1,000 amperes at 35 volts for one hour.

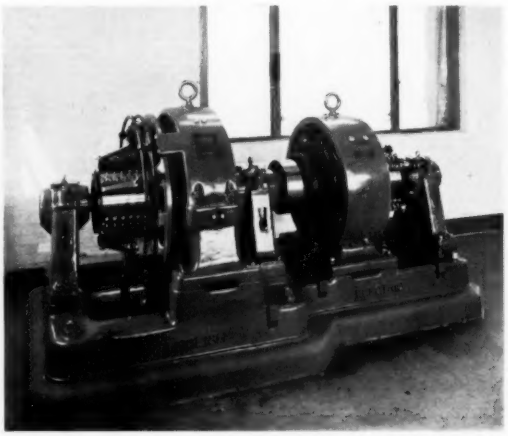
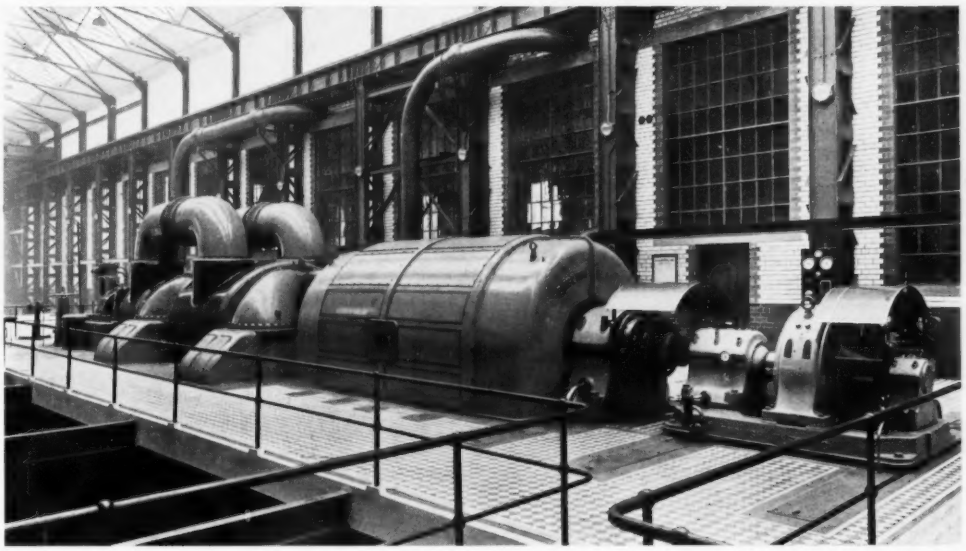


Fig. 10. 1000-ampere Reversible Booster for Battery Charging at Brookman's Park.

For the control of the Power Station plant and of the various circuits and individual machines, a number of "English Electric" switchboards has been installed, of which the most important are the 10-panel power station board and the 25-panel board in the Transmitter Hall which controls the output sides of the high-tension and filament current sets and other auxiliary machines.

It is satisfactory to be able to record that following the successful operation of the London Regional Station an order was placed with this Company for similar electrical plant for the Northern Regional Station which is now being erected at Slaithwaite, near Huddersfield. Generally speaking, the machines and auxiliary apparatus will be similar to those for the earlier station.

Opening of Extensions to the Central Generating Station, Leicester.—New 25,000 kW. Set.



The remarkable progress of the City of Leicester's electricity undertaking is indicated by the threefold increase in the number of units sold, which has occurred in the last ten years; 56½ million units were generated during the last nine months of 1929. The latest stage in the development of the undertaking was marked by an inaugural ceremony on February 19th, when Sir Andrew Duncan, the Chairman of the Central Electricity Board, formally started up the first of two 25,000 kW. generating sets for which accommodation has been provided.

Leicester is fortunate in having a very progressive Electricity Committee, and especially so in its enthusiastic Chairman and Vice-Chairman Councillors A. H. Swain and John Minto, who, together with the Engineer and Manager, Mr. John Mould, who planned and supervised the work, have been largely responsible for the carrying through of the extensions.

Since this Company were the main Contractors for the construction of the Power Station, which was completed in 1922, they have installed 44,500 kW. of main generating plant in it, including the new 25,000 kW. set. This set, a photograph of which is reproduced, is driven by a 3,000 r.p.m. turbine of the multi-cylinder type in which the Company has specialised for several years. This particular turbine is generally similar to the 20,000 kW. set at Bradford, and to the two-cylinder machines supplied to Budapest and elsewhere. It includes a single H.P. turbine of the impulse type, and a double-flow L.P. turbine of the reaction type.

The vacuum at Leicester being moderate it was not necessary to carry the development quite as far as in the case of the larger machines for West Ham, Bradford, and the Thornhill Station of the Yorkshire Electric Power Company. In these three sets the L.P. turbine is separated into two distinct turbines.

The Leicester turbine is designed to operate with steam at a pressure of 350 lbs. per sq. in., and a total temperature of 750° F., and exhausts into an "English Electric" twin Condenser which maintains a vacuum of 28·45 ins. of mercury. The alternator has closed-circuit cooling, the cooler being connected to the circulating water system of the turbine condenser.

Shin Keihan Railway—Japan.

In an earlier article* published in this Journal, a description was given of the equipment, and particularly of the automatic substations, on the Keihan Electric Railway, which, until a few years ago, was the only electric line connecting Osaka, the largest industrial city of Japan, with Kyoto, the old capital. In that article it was explained that this busy district was served at one time only by the steam line of the Imperial Government Railways, but that in 1910 the Keihan Company commenced their electric service which in course of time became one of the busiest in Japan. The enormous growth of the traffic carried on this line led eventually to a proposal for the construction of a new electric railway, the Shin (New) Keihan Railway, for the double purpose of relieving the older line by running an express service between the two cities and also of serving the numerous villages on the west side of the River Yodogawa. Until this new line was opened these villages had to rely solely upon the steam service of the Imperial Government Railways, on which local stopping trains were somewhat infrequent.

The necessary permission having been obtained from the Government and the land purchased, the track was run almost parallel to the existing I.G.R. steam line, as can be seen from Fig. 2.

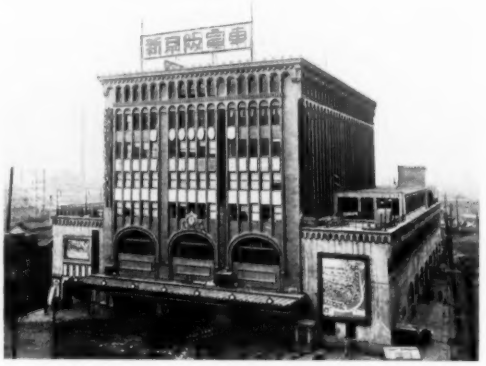


Fig. 1.—Tenroku Terminus, Osaka.

The aim of the engineers throughout was to secure as much straight track as possible, and an indication of the success attained is given by the view in Fig. 3. The longest length of track without a curve is six miles; the minimum radius 20 chains, and the steepest gradient one-in-a-hundred. Fig. 1 illustrates the Tenroku terminus at Osaka.

The Shin Keihan line which was opened in its entirety on November 1st, 1928, gives an express service at intervals of thirty minutes which covers the distance of 25½ miles in thirty-eight minutes; stopping trains run every twelve minutes, and are scheduled to do the journey in fifty-two minutes.

There is an underground extension of the line from the Saiin terminus in Kyoto to Shijyo Kawaramachi, and a branch line has also been constructed to Arashiyama, one of the beauty spots of the country. The view of Arashi-

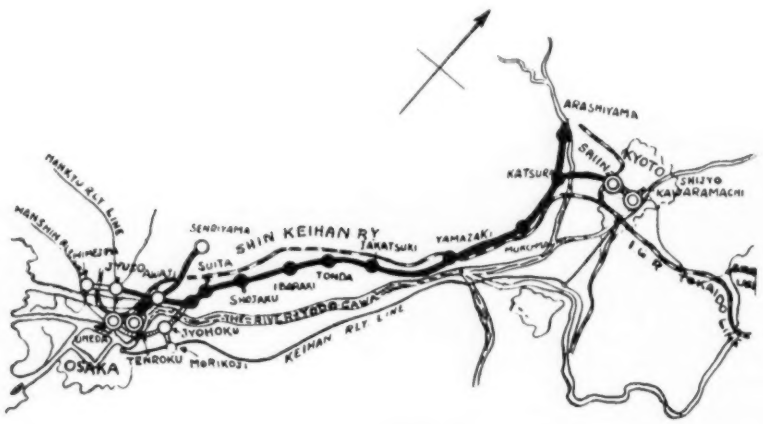


Fig. 2.—Railways between Osaka and Kyoto.

*Vol. IV No. 7.

yama station reproduced in Fig. 7 gives some indication of the skill with which an entirely modern layout suitable for handling large volumes of tourist traffic, has been given a distinctively national and pleasing architectural effect.

In accordance with the recommendation of the Imperial Government Railways for all new railway electrifications in Japan, the 1,500-volt direct-current system was adopted. Two large sub-stations were erected, one at Shojaku, and the other at Mukomachi, each with a capacity of 6,000 kW., and with space for extensions up to 9,000 kW. Both substations are similar in construction, and are equipped with 750-volt rotary converters operating in pairs in series for the supply of the 1,500-volt overhead lines. These 1,500 kW. machines, which are amongst the largest of their type in Japan, are of The English Electric Company's tap-started design, and have shunt windings separately excited from an exciter fitted to one machine of each pair. They are equipped with roller bearings having oil lubrication and run at a speed of 600 rpm. Control is by means of the company's automatic switching equipments embodying their electrically-driven camshaft controllers. Power is supplied to the substations by 22,000-volt, 60-cycle, 3-phase feeders, and this supply is stepped down by two 3,200-kVA. 3-phase transformers in each station, one transformer serving a pair of 1,500-kW. series-connected convertors.

Fig. 4 is a general view of the Mukomachi sub-station, and Fig. 5 shows the interior from the control gallery. Both substations operate in parallel, and are linked at Takatsuki through high-speed circuit-breakers.

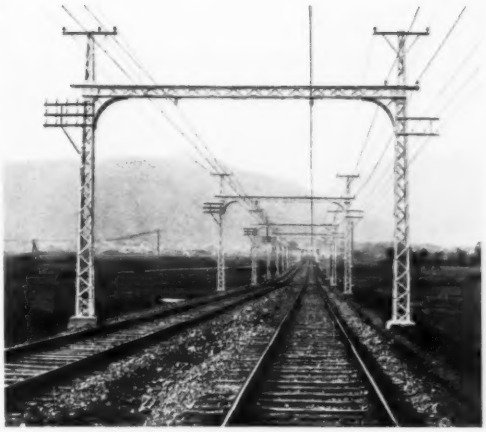


Fig. 3.—A Stretch of Straight Track.

The 22,000-volt switchgear is housed in stone-work cubicles, and the oil breakers are operated by D.C. solenoid gear.

Starting up and synchronising of each 3,000 kW. 1,500-volt unit, that is to say, a pair of convertors, takes place automatically after the attendant has closed the control switch, and full protection is provided both on the D.C. side and on the A.C. supply by means of high-speed circuit breakers, and the various protective devices referred to in detail below.

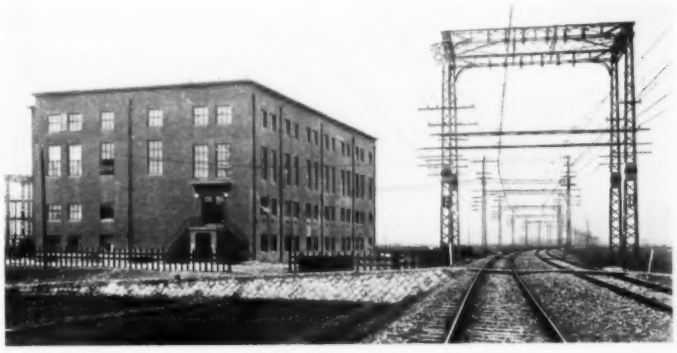


Fig. 4.—Mukomachi Substation.

The starting switchgear in each substation comprises a camshaft controller and relay panel for each machine (see Fig. 6), and these panels are mounted below the switch gallery seen in Fig. 5.

The sequence of operations at starting up is as follows :—

Provided the master interlocking circuit is correct, thus ensuring that the two camshaft controllers for the pair of machines are in the correct starting positions, that the D.C positive contactor and high-speed

Fig. 5.—Interior of Mukomachi Substation.

breaker are open, and that the incoming supply is available, both convertors start up when the control switch is operated. The main oil breaker first closes, and the camshaft controllers apply the necessary low-voltage to the convertors which then run up with their fields short-circuited for an interval across discharge resistances. As the exciter is direct-coupled to one of the convertors its voltage begins to build up, and when it has reached 80 per cent. of its full value the field-making relays of both machines begin to move against a time lag. After an interval of about 20 seconds, one pair of contacts on the relay of one machine connects the convertor field across the exciter through a reducing resistance, thereby pulling that machine into synchronism on a weak field. After a further interval of about 10 seconds the relay of the other machine closes, and it also is brought into synchronism.

Correct polarity is checked by a synchronising relay on each machine, which also brings about the further rotation of the camshaft controller, by means of which the sliprings are disconnected from the tap voltage and connected to the full voltage, first through chokers and then direct, and the field discharge and reducing resistances are cut out. The controller takes less than 3 seconds to complete the above-mentioned operations.

Upon reaching the full running position the controller is brought to rest by the opening of a contact which de-energises the camshaft motor relay and short-circuits the armature of this motor, thereby bringing it sharply to rest. The controllers of the two machines of a pair follow the same sequence with a brief time interval which is determined by the difference in timing of the respective field making relays.

When both controllers reach the full running position a white lamp on the D.C. board lights up and thus indicates to the attendant that he can close the main D.C. breakers. The negative high-speed breakers are first closed and then the positive contactor, and the unit is ready to take load. An interlock is provided so that the high-speed breakers must be closed first. The 3000-ampere machine high-speed breakers are situated in the negative lead of the pair, and between the positive of the low machine and the commutation pole circuit of the two machines respectively. A contactor of the same rating, with maximum, reverse and low-voltage releases, is connected in the positive lead of the machine pair.

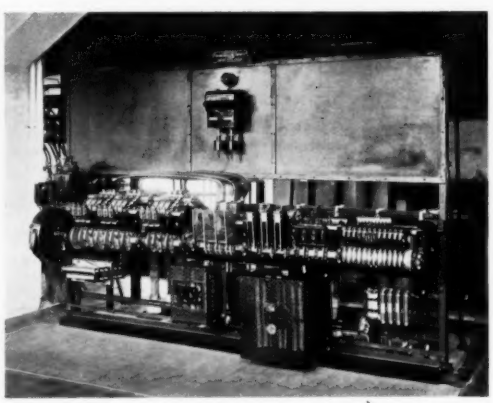


Fig. 6.—A Camshaft Controller and Relay Panel.

Finally, the D.C. feeder high-speed and slow-speed breakers are closed by a control switch and manual operation respectively, and here again an interlock is provided to ensure that the high-speed breaker is closed first.

When any of the D.C. contactors, high-speed circuit-breakers or A.C. oil-breakers trip, an alarm bell rings until the attendant moves the control switch of the breaker which has operated to the " off " position. When a unit shuts down, due either to the attendant tripping an oil breaker, or by the operation of an automatic trip, a circuit is completed to the camshaft motors and relays of both controllers, and these immediately run back to the start position, thereby leaving the equipment ready for restarting.

The following is a brief summary of the protective features of the equipment :—

A heavy overload or short-circuit on the D.C. side will usually cause the feeder slow-speed or high-speed circuit-breaker to trip, and in the event of a very severe short-circuit the machine high-speed breaker will trip. Protection is also given against overspeed, field failure, A.C. overload, A.C. undervoltage or failure, and D.C. reverse current.

Fig. 7.—Arashiyama Station.

With a few minor exceptions the whole of the substation equipments were supplied by this Company, and the erection of the substations and their successful inauguration was carried out by the engineers of the Shin Keihan Company.

The rolling stock of this line is of the most modern description, and has for a large part been equipped with " English Electric " motors and camshaft control gear, manufactured either at Preston or by Messrs. Toyo Denki Seizo KK. to " English Electric " designs. The motor coaches, which are equipped with four 200 h.p. motors, are some of the most powerful now in service in Japan. They are of the all-steel type, 60 ft. long by 9 ft. 6 in. wide, with very comfortable seats and ample space, and have a service speed of up to 55 m.p.h. In addition to being some of the first coaches in that country to be fitted with the Westinghouse A.M.U. compressed air brake, they have also automatic electro-pneumatic door-closing apparatus. The normal make-up of the trains consists of a motor coach and a trailer, two motor coaches and a trailer, or three motor coaches and two trailers.

Fig. 8.—One of the Car Sheds.

Brickworks Electrification.

In the following article attention is drawn to the extensive use of electric power for a wide variety of purposes in the brickmaking industry. By kind permission of the Cattybrook Brick Company Limited, and through the courtesy of "The British Clayworker," we reproduce from that Journal some particulars of a modern electrically-operated brick-yard.

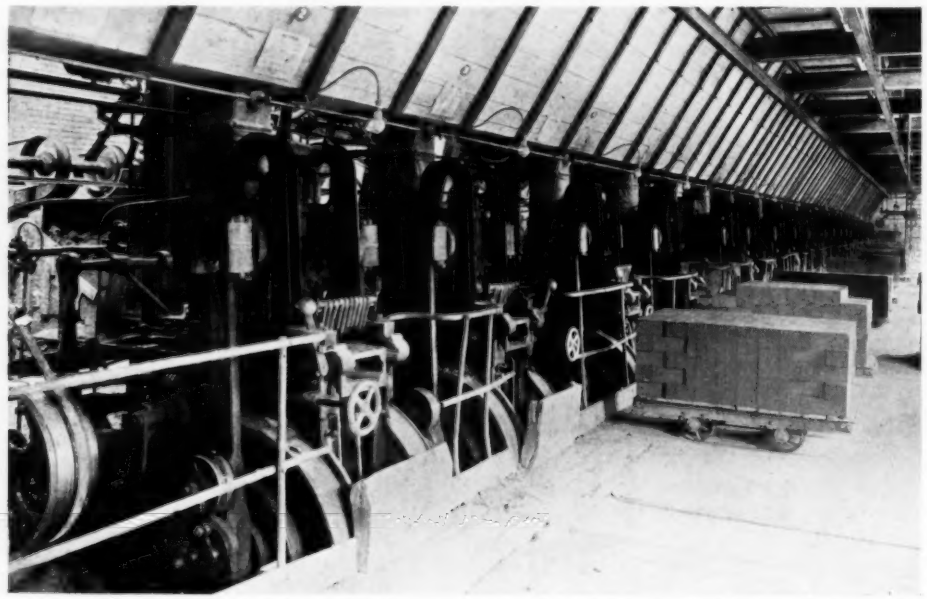


Fig. 1. A Battery of Brick-making Presses in one of the yards of the London Brick Co. and Forders Ltd.

Most brickmakers in this country made full use of the opportunity given them by the enormous demand for their products after the War, by introducing many improvements in their organisation and manufacturing methods. The use of electric power, introduced primarily as a measure of undoubted economy in place of the old steam engine drives, led in this industry as in so many others to the development of a new operating technique based upon the facility with which power measurements could be made with the new form of drive.

Of the many brickworks with which this Company has been associated in connection with electrification, probably none is so well known or of such large size as the undertaking of the London Brick Company & Forders Ltd., whose yards in the neighbourhood of Peterborough and Bedford are landmarks on the main lines of the L. & N.E. and L.M. & S. Railways. The results obtained by the electrification of their No. 1 Yard at Peterborough were so satisfactory that following this first installation The English Electric Company has supplied equipment for no fewer than twenty yards connected with the "Fletton" brick industry. This material has included motors of from 2 h.p. to 400 h.p. aggregating more than 10,000 h.p. in all, together with transformers, high-tension and low-tension switchgear, rotary convertors and electric locomotives. At the present moment the Company is engaged in installing plant in three brickworks.

As mentioned above, the ease with which accurate data of the power consumption can be obtained under electric working enabled considerable economies to be effected by modifying the brickmaking machinery. For example, it was found that the speed at which Grinding Pans

had been run was too high and by reducing this speed by less than 25 per cent. the power consumption was halved without affecting the efficiency of the grinding. A further economy was effected by fitting alarm bells to warn the machine operators when the motors were being overloaded, as this reduced the maximum demand and consequently the cost of power purchased on a maximum-demand tariff. It was also found that the use of electric driving could be advantageously extended further than was originally contemplated; thus the steam-driven navvies were replaced by electrically-operated machines, and the old steam pumps of the pulsometer type by motor-driven centrifugal pumps. In a number of works, motor-driven fans are used to improve and control the draught conditions of the kilns and as a consequence the time the bricks are in the kiln has been reduced.

A marked increase of output, of the order of 10 per cent., resulted from the improved steadiness of the drives; in the old days the steam engines used to labour and slow down under certain working conditions, particularly when the clay was wet.

The cost of power per 1,000 bricks produced has been reduced by more than 50 per cent. by the introduction of electric power, and in some cases where it has been possible to work a double shift the saving has been as much as 67 per cent.

"English Electric" plant is installed in all the electrified brickyards at Peterborough, Bedford, and in Buckinghamshire, which produce the ordinary "Fletton" pressed bricks that are used so extensively for all classes of building. The output is very great, and had increased at the end of March last to a figure of over 100,000,000 bricks per month.

Fig. 2 illustrates a 400 h.p. Induction Motor driving a range of grinding pans and presses at the Pillinge Works, near Bedford, of the London Brick Company, and Fig. 1 a line of brick presses.

Whilst this Company has been intimately concerned with the electrification of the yards in which "Fletton" pressed bricks are made, it has also electrified a number of yards in other districts where it is the practice to use what is known as the "pug-mill." There are many such

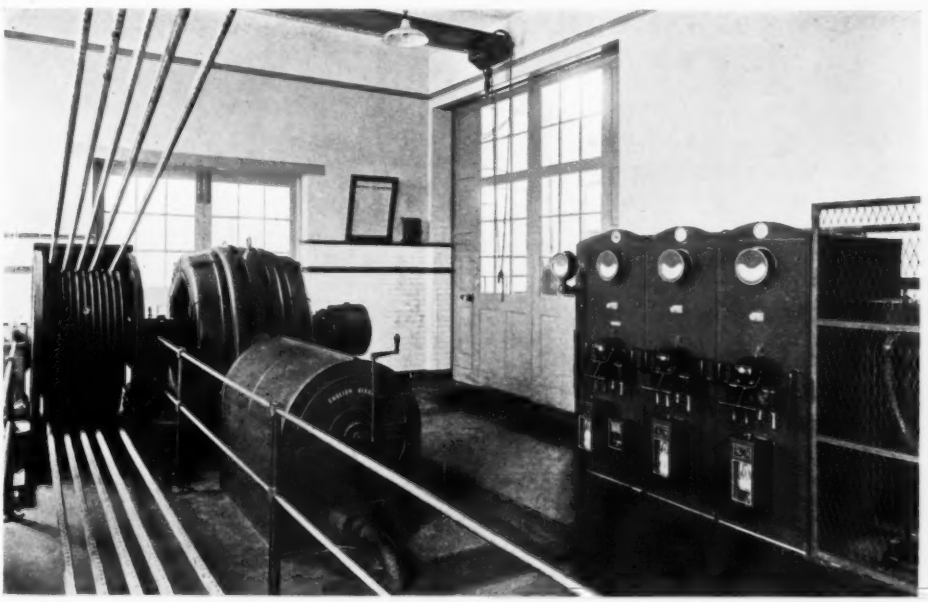


Fig. 2. 400 H.P. Three-phase Motor driving a range of Presses, and substation equipment.

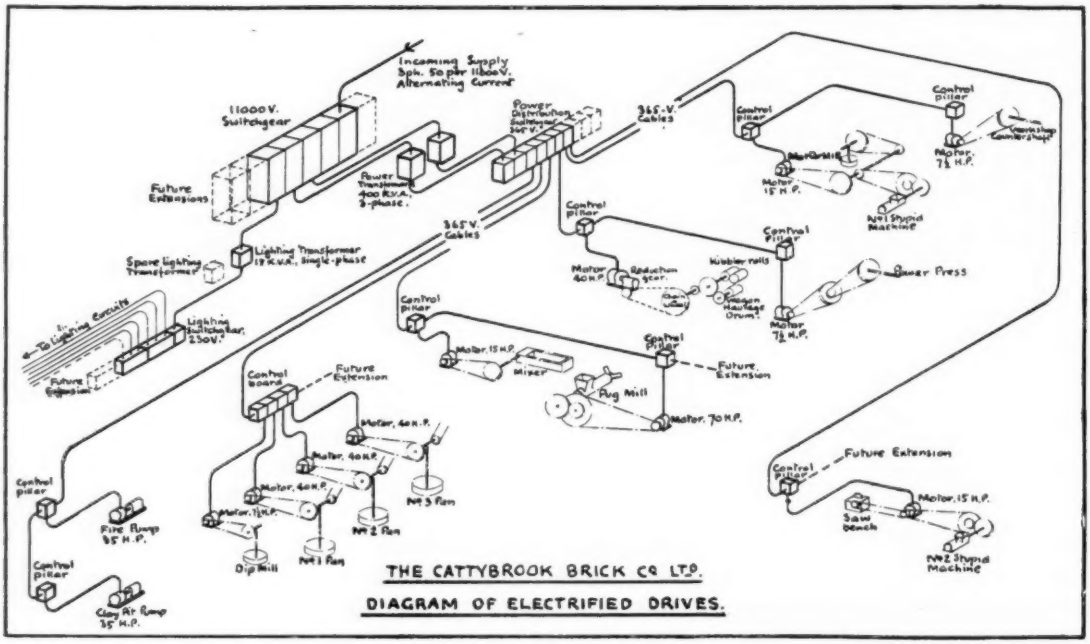
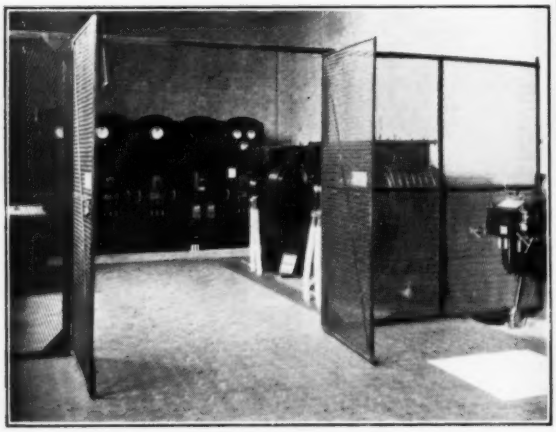
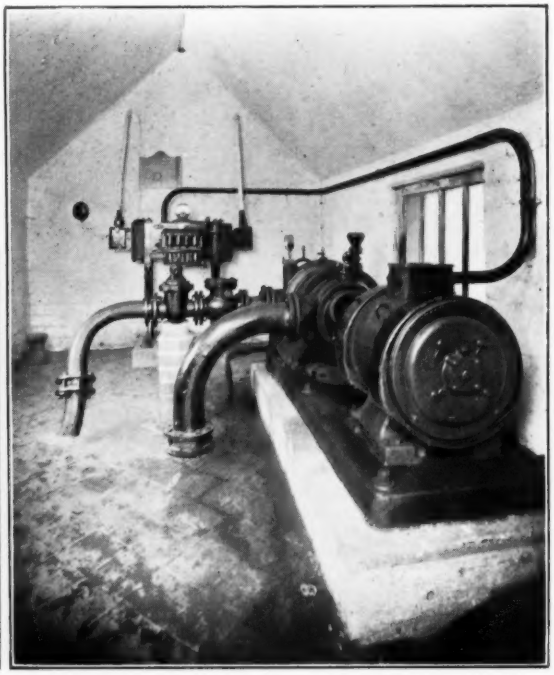


Fig. 3. Diagram of Drives at the Cattybrook Co.'s yard.

Fig. 4. Transformers and H.T. Switchgear.

Fig. 5. Fire Pump.





works in the Midlands, but the example selected for description is the Almondsbury Branch of the Cattybrook Brick Company, near Bristol.

These Works have long been a well-known landmark to the travellers on the G.W.R. system to or from South Wales via the Severn Tunnel. The works, indeed, owe their origin to the Tunnel, for it was in connection with the original cutting for that great engineering undertaking that the beds of clay were discovered by the late Mr. Charles Richardson, the Engineer in charge, which were destined to make the name of Cattybrook respected wherever bricks of quality are under consideration.

Begun as far back as 1864, the works quickly became famous for the quality of their manufactures, which include Red, Blue, Buff, Brindle and Rustic-faced Bricks, Terra-Cotta goods, Flooring Tiles, Quarries, etc. It is no exaggeration to say that from the point of quality and colour Cattybrook bricks rank as high as any in the country, and they are used extensively throughout the South and West of England and South Wales for the erection of Churches, Schools, Public Institutions, Railway depots and bridges, as well as being in demand for factories and works requiring materials combining great strength and pleasing appearance. No less than thirty millions of Cattybrook bricks were used in the construction of the Severn Tunnel, whilst to instance two only of many firms of world-wide reputation whose factories and offices have been erected exclusively of Cattybrook Bricks and Terra-Cotta, may be mentioned those of The Imperial Tobacco Co. (of Great Britain and Ireland), Ltd., and Messrs. J. S. Fry and Sons, Ltd., household words with British people.

Previous to electrification, the various brick-making machines, pumps, etc., were driven by a number of old-fashioned, single-cylinder steam engines, these being, in several cases, located in positions remote from the boilers.

Only the main mill engine ran condensing, and in only one case did conditions permit of the utilisation for heating purposes of the steam exhausted from the others. The main mill engine drove the three grinding pans, the mixer and the dip mill through a network of gearing, countershafts, ropes, etc., so arranged that all these machines had to be in motion when the engine was running, no matter whether all were in use or not.

Under such conditions it is not surprising that the efficiency of the engines plus transmission mechanism should have been a low one, and this consideration, coupled with the increasing risk of breakdown due to advancing age of the engines, led to the decision to replace them.

The following alternatives were considered :—

(*a*) Electrification of the scattered lighter drives and the replacement of the old main mill engine by a new steam or oil engine to provide mechanical power direct to the bunch of heavier drives, and to drive a generator for supplying electrical energy to the motors for the lighter drives.

(*b*) Complete electrification of all the drives, both light and heavy, and the installation of a new steam or oil engine generator set, to provide the electrical energy required.

(*c*) Complete electrification of all the drives, and the purchase of an external supply of electrical energy from the mains of the Bristol Corporation.

Alternative (*a*) was ruled out of consideration because individual operation of each of the heavier drives could not be provided for. Complete electrification was therefore decided upon.

When considering the relative advantages of oil and steam in the case of alternative (*b*), the possibilities of future increase in the demand for steam for heating purposes was explored. It was found that these were negative, and that the greatest quantity of steam which would be needed for heating purposes would be negligible compared to the quantity required for power production. Furthermore, the replacement of the old mill engine by a new steam engine, while it would improve reliability, would effect merely a nominal improvement in economy. Steam as a source of motive power was therefore rejected.

Selection, therefore, lay between independent generation by oil, and external supply. As the driven machines run at constant speed, the alternating-current type of motor, with its advantages over the continuous-current type in respect of simplicity, robustness of construction and low maintenance cost, could be employed,

and (the external supply being an alternating-current one) costly and wasteful converting plant could be dispensed with.

It was found, after capital charges on both sides had been allowed for, that there was little to choose between the total cost per unit generated in either case when working 48 hours a week, the normal condition. Seeing that the purchase of a supply entailed a much lower capital expenditure and, moreover, relieved the Cattybrook Brick Co. of responsibility for power production, it was decided to take it.

The characteristics of the electrical scheme adopted are indicated diagrammatically in Fig. 3. The current is received from the Corporation into the E.H.T. Switchboard at 11,000 volts, three-phase, 50 periods. After passing through the Corporation's metering cubicle, it passes to three feeder cubicles, the first controlling a 400 k.v.a. three-phase 11,000/365 volts oil-immersed transformer for power purposes; the second controlling a similar transformer as stand-by; and the third controlling a 15 k.v.a. single-phase 11,000/230 volts oil-immersed transformer for lighting purposes. Should one of the power transformers break down, the other can immediately be put into commission, the transformers being run turn and turn about to ensure that the one which is idle for the time being is always ready for immediate service. A spare lighting transformer is also provided to replace the one in service in case of breakdown of the latter.

In addition to the usual protective devices, instruments and meters, the 11,000 V. Switchboard is fitted with a Maximum Demand Indicator which visibly records on a clock-driven chart the "Maximum Demand" during every successive 15 min. interval, this being the Maximum Demand interval on which the supply tariff is based.

The Charts can be read while still in process of delineation on the instrument, from which they are detachable on completion. Irregularities can be detected from the charts at a glance, and, since the times when these occur are also recorded, it will be seen that they provide the Manager with the information needed to enable him properly to investigate their causes. The charts also render further service to the Manager, in that they provide him with a continuous record of the changes in maximum demand which result from changes in working conditions, such as variation in wetness of clay, "the human element," mechanical defects, or faulty adjustment to the driven machinery.

The indicator is also fitted with an attachment which, by automatically tripping the power circuit, limits the Maximum Demand to a figure which it is desired not to exceed. Electrical power tariffs are in the vast majority of cases based in part on maximum demand, the charge for this being computed from the "peak" recorded over a certain period of time. There are some tariffs in which this period is a short one only—perhaps a month. In that case the charge would be computed on the highest demand recorded over a month's running, the recording instrument being reset after each month's reading has been taken. On the other hand, there are many other tariffs (including the one in question) which do not permit of the instrument being so reset, but provide that each successive "peak" shall be regarded as the basis for all future charges over the unexpired period of the agreement. Where tariffs such as the last-mentioned obtain, it is obvious that some quite accidental circumstance—such as the stalling of a pugmill—may force up the maximum demand to an abnormal figure, and thereby impose a heavy and permanent increase in the cost of current. It is to obviate such a contingency that the automatic tripping device has been installed.

From the low-tension sides of the power transformers the current passes to a pillar-type switchboard, whence it is distributed to the various main power circuits. A switchboard of similar type is employed to control the main lighting circuits.

The gear above mentioned is housed in a building 45 ft. long and 20 ft. wide, converted from a clay-storage shed into a substation, an interior view of which is given in Fig. 4.

The high- and low-tension power cables are of paper insulated, lead-covered, double-wire armoured type, properly insulated for their respective voltages. The cables leading from the

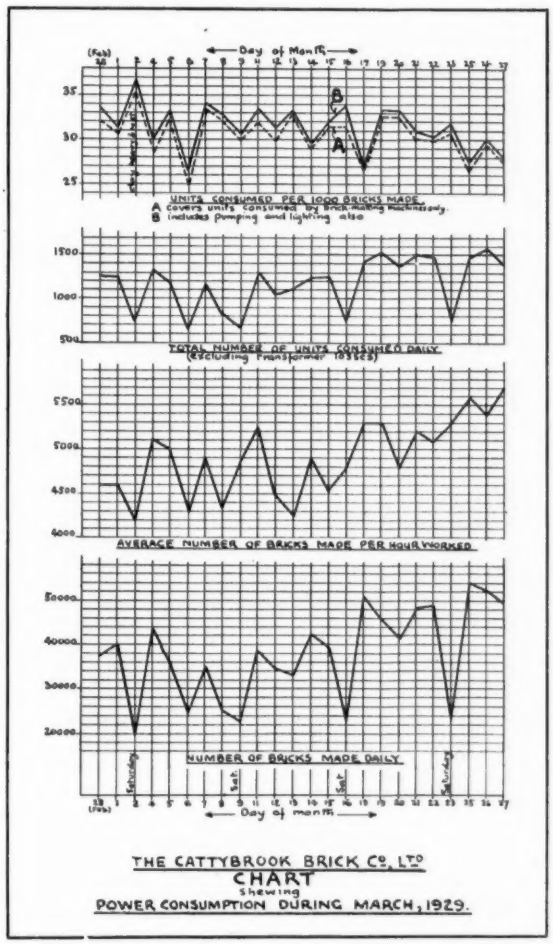


Fig. 6. Chart showing Power Consumption.

substation to the motors are suspended between buildings from wire catenary spans.

The installation of the motors demanded special care because it was essential that the conversion from steam to electrical drive should be effected without interruption to the normal running of the works. The work was therefore carried out over a number of successive week-ends. The restricted period thus available for each conversion set a limit to the extent of the alterations to the existing shafting and gearing which could be attempted. Some of the drives, therefore, represent a compromise with the ideal attainable, had a longer time for conversion been permissible.

The congested character of the buildings also made it difficult to find locations for the motors which would enable effective drives to be employed, and at the same time permit of the construction of proper seatings to carry the motors. The seatings for both motors and starters were, as far as possible, prepared in advance, so as to encroach as little as possible on the short time available for the installation of the electrical gear and for the alterations needed to the shafting. The substation had been completed and the switchgear and transformers installed in readiness before conversion of the drives was commenced. Each drive was started up on commercial load at the usual time on the Monday morning following completion, and the complete change-over was effected with the loss of the minimum amount of running time.

For the brickworks motors, normal full load ratings of 70, 40, 15 and 7½ B.H.P. were selected as standards. All sizes are wound for 3 phase 50 periods 365 volts alternating current. They run at a synchronous speed of 600 r.p.m., and are of the squirrel-cage type, with roller bearings.

Squirrel-cage motors were selected on account of their simpler design, their higher efficiency and better power factor as compared with slip-ring motors, and because they have no rubbing contacts. On most of the drives, and on all the heavy ones, the motors are fitted with automatic centrifugal friction clutches, which come into operation when the motors have attained about 75 per cent. of their normal full load speed. These motors are provided with auto-transformer starters, the clutches being so adjusted that they do not come into operation until the starters have been thrown into their running positions. This arrangement helps to neutralise the inherent disadvantage of squirrel-cage (as compared to slip-ring) motors, in respect of their lower starting torque and heavier starting current.

All the motors are of the standard enclosed ventilated type. Pipe ventilation was considered, but was abandoned owing to the impossibility of making the ducts long enough to reach air uncontaminated by clay dust, to the continuous

attention needed by air-filtering appliances in dusty situations, and to the dangers attendant on neglect in cleaning the filters. Clay-dust naturally finds its way into the windings of the motors, but is readily blown out by compressed air at weekly intervals.

The brickworks motors, with the exception referred to below, transmit their power through belts. The arrangement of the belt drives calls for no special comment.

The exception mentioned is the drive for the kibbler rolls, in which the full load motor speed is 577 r.p.m. and that of the driven shaft 6·5 r.p.m. This large speed reduction is obtained by means of a Wallwork totally enclosed and force-lubricated compound worm and spur gear, the slow speed shaft of which drives the 6·5 r.p.m. kibbler shaft through a Renold duplex bush-roller chain, totally enclosed in a gear case adapted for oil-bath lubrication. Roller or ball bearings are employed throughout the reduction gear.

In cases where it was found impossible to place the starter immediately alongside the driven machine, push-button tripping switches, mounted in a convenient position, are provided to ensure that the motor can be stopped at once in case of emergency.

The fire and drainage pumps are of centrifugal type, and driven by squirrel-cage motors of 35 b.h.p. As the drainage pump is situated in a deep cutting remote from the works, arrangements are made so that it can be shut down automatically by a float switch when the water has been lowered to a proper level, and alternatively tripped by hand from the surface.

The pump motors are provided with drip-proof protection, and are duplicates of each other.

Advantages of Electrical Driving.

Electrification has made it easy accurately to observe and record the effects of changes in conditions which could only be guessed at when the steam-driven plant was running. For instance, before it was carried out the only method (and that a rough one) of ascertaining the power absorbed by each pan, was to drop the load on each pan in succession and to indicate the engine at each stage, whereas the load on each pan can now be read directly from the ammeter. The effects of changes in the quality of the clay, and of the quantity passing through the pans, are now immediately visible to the attendant, and can be corrected for accordingly. The effect of adjustments made to the bearings and mechanism of the driven machines can similarly be observed with accuracy.

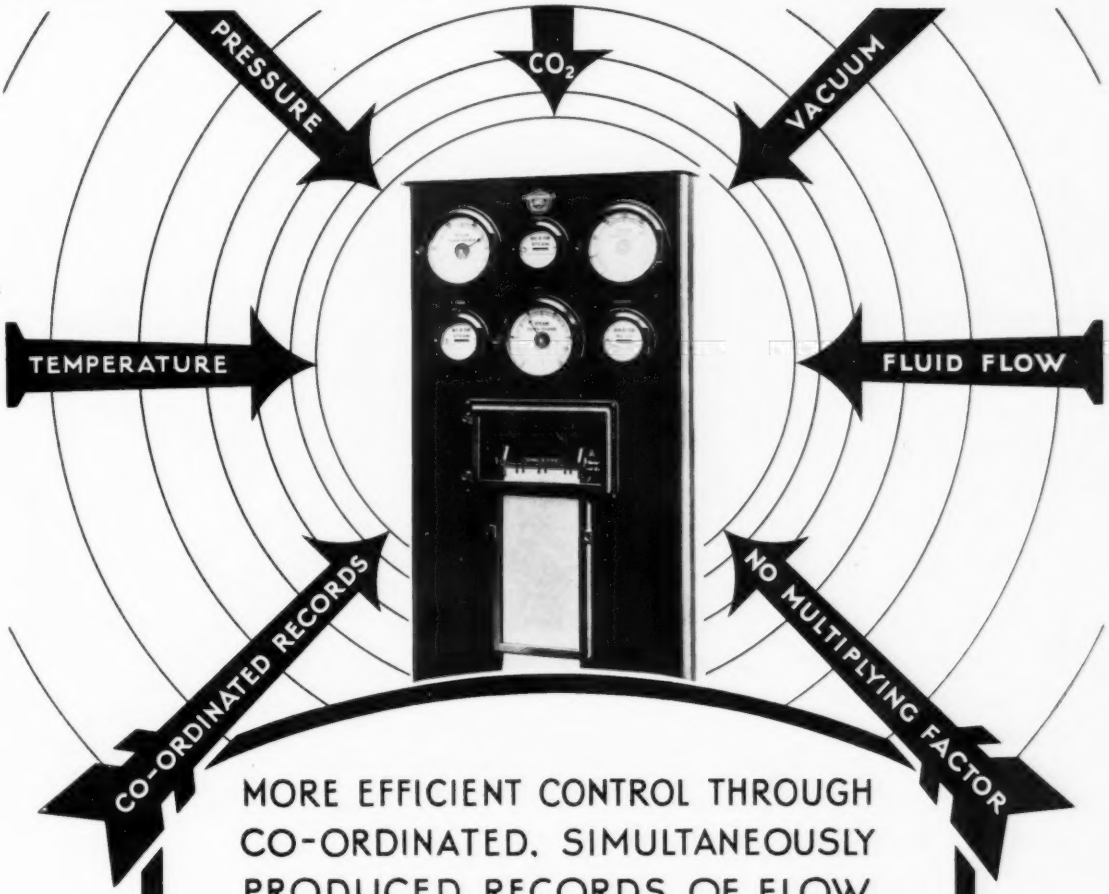
The improvement in regularity of the flow of clay through the pans which can now be effected enables the clay to be ground to a more uniform consistency, and thus improves the average quality of the bricks produced.

In respect of the pumping plant, the advantage of electrification is also great. In the case of the fire pump, a proper supply of water at constant pressure is now immediately available in case of emergency, whereas with the old steam pump full pressure could not be obtained for some time, owing to steam pipe and cylinder condensation, etc., and to lack of steam. The new drainage pump too, possesses a similar advantage, and, in addition, that of clearing surface water much more promptly and expeditiously than the old one, thereby enabling operations at the working face, interrupted by flooding, to be sooner resumed.

The Chart (Fig. 6) shows the current consumption during March, 1929, plotted against the output of bricks over the same period. It indicates the precision with which variation in power consumption (due to fluctuation in output, variations in clay conditions, or other causes) can be recorded and detected. Such a chart enables the manager to assess a standard value for power consumption in relation to seasonal output ; any material variation from which will indicate the operation of special conditions which need investigation.

The arrangements for conversion were planned, and specifications for the equipment prepared, by Messrs. Plevin and Jenkins, Consulting Engineers, Cardiff, to the instructions of Mr. E. Gwynne Vevers, the Managing Director of the Brick Company.

The English Electric Co., Ltd., provided the motors, starters, and cables, and carried out the changes to the driving arrangements.



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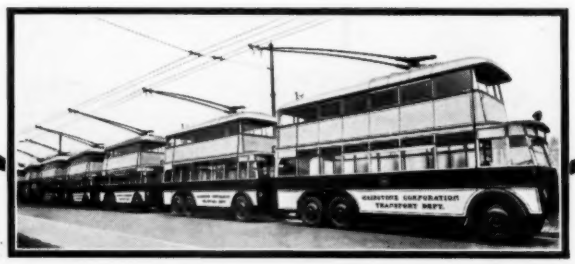

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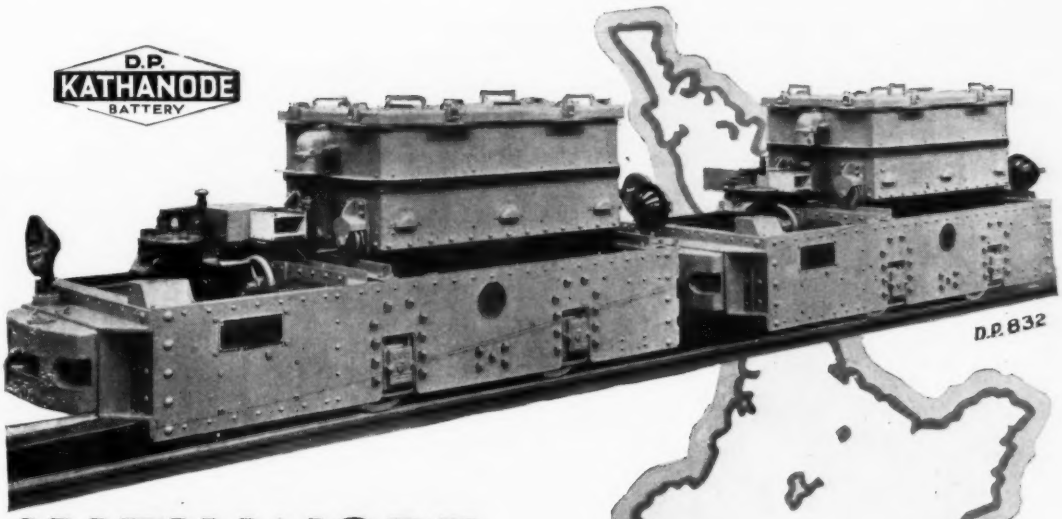

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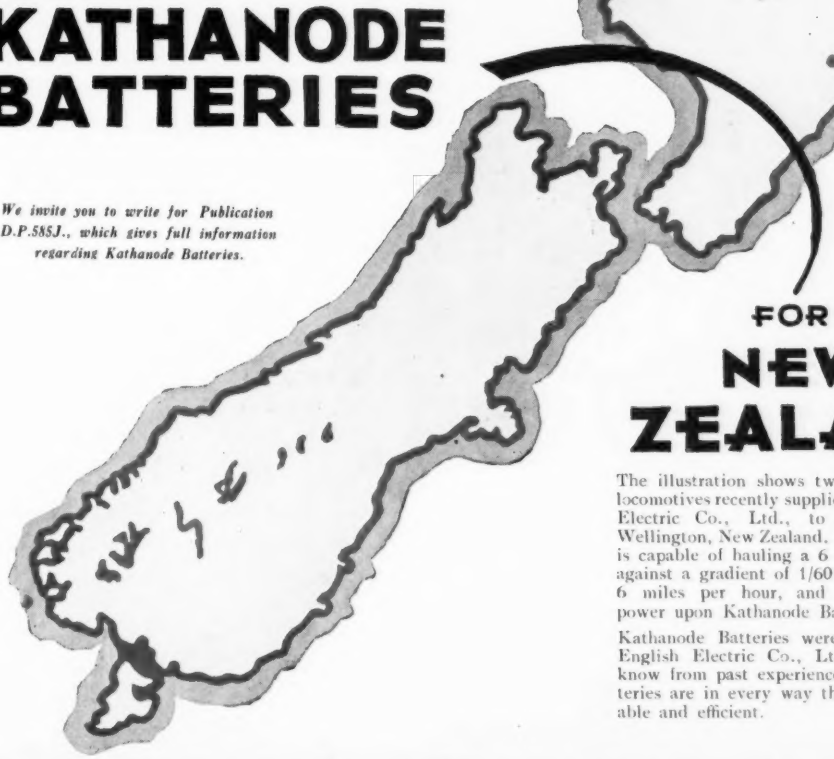

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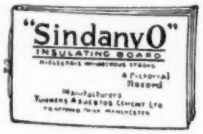

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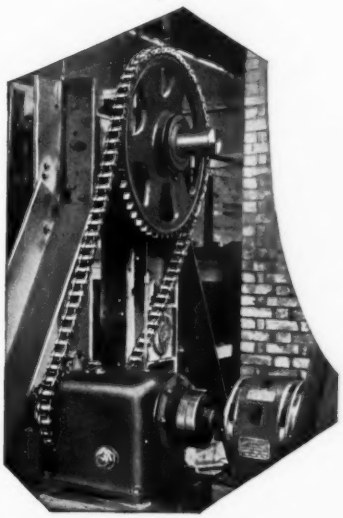

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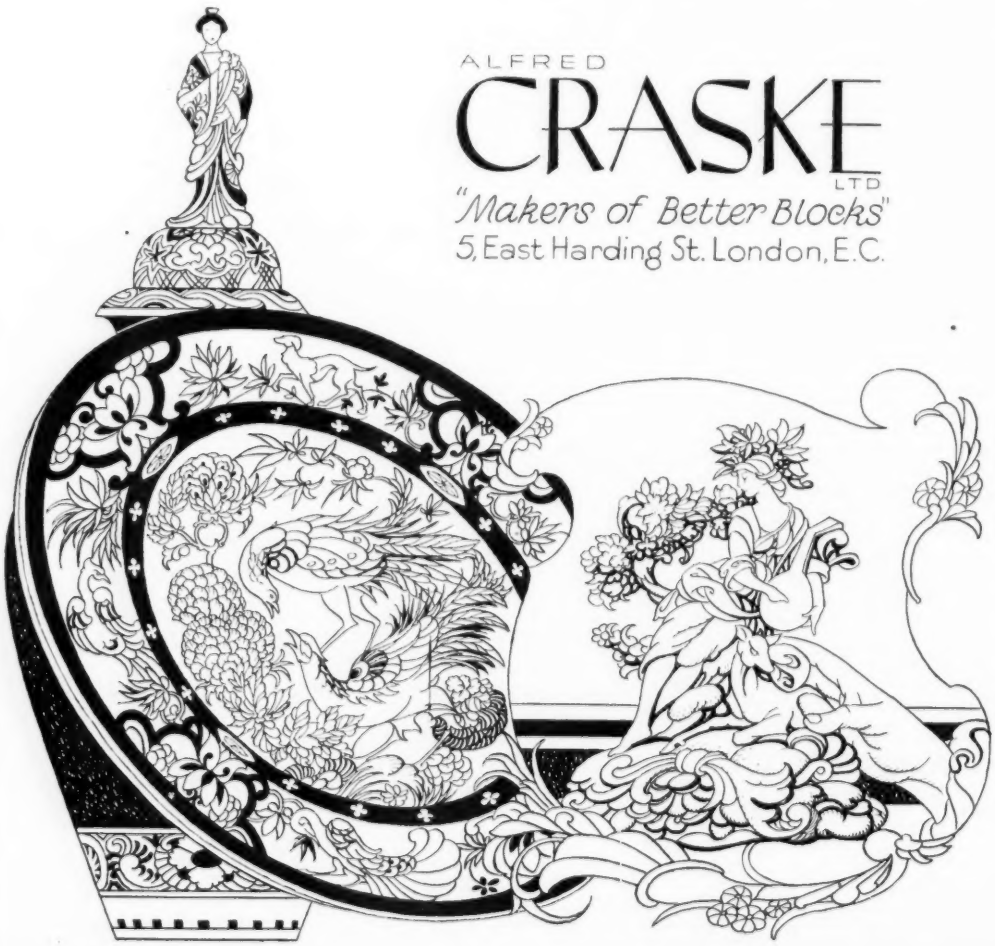

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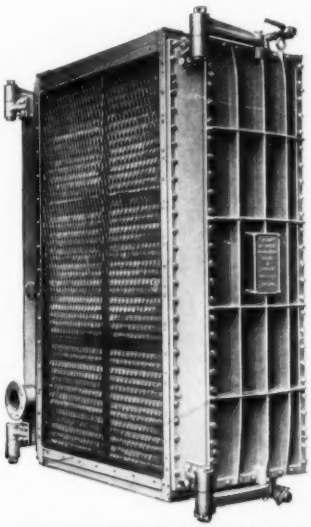

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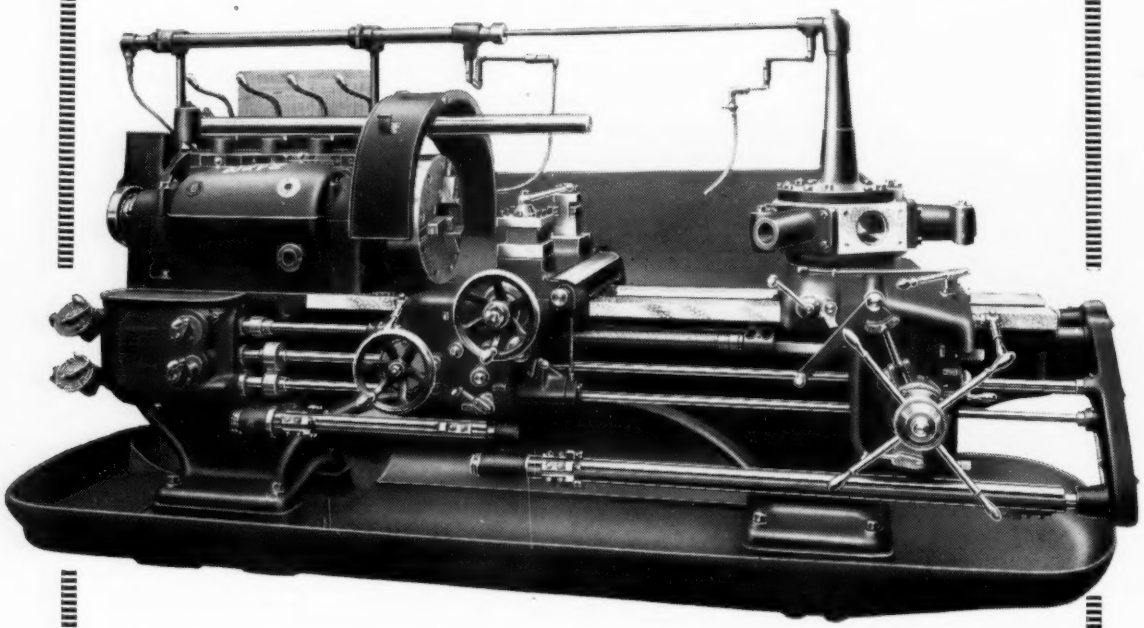

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